# CHAPTER 1. RECOMMENDATIONS HIGH-ALTITUDE ALTITUDE TRAINING

**1. PURPOSE.** This chapter presents an outline for recommended high-altitude training that meets the requirements of FAR § 61.31(f). The actual training, which may be derived from this outline, should include both ground and flight training in high-altitude operations. Upon completion of the ground and flight training, the flight instructor who conducted the training should provide an endorsement in the pilot's logbook or training record, certifying that training in high-altitude operations was given. A sample high-altitude endorsement is available in the most recent version of AC 61-65, Certification: Pilots and Flight Instructors.

***a. Although FAR § 61.31(f)*** applies only to pilots who fly pressurized airplanes with a service ceiling or maximum operating altitude, whichever is lower, above 25,000 feet MSL, this training is recommended for all pilots who fly at altitudes above 10,000 feet MSL.

(1) A service ceiling is the maximum height above MSL at which an airplane can maintain a rate of climb of 100 feet per minute under normal conditions.

(2) All pressurized airplanes have a specified maximum operating altitude above which operation is not permitted. This maximum operating altitude is determined by flight, structural, powerplant, functional, or equipment characteristics. An airplane's maximum operating altitude is limited to 25,000 feet or lower unless certain airworthiness standards are met.

(3) Maximum operating altitudes and service ceilings are specified in the Airplane Flight Manual.

***b. The training*** outlined in this chapter is designed primarily for light twin-engine airplanes that fly at high altitudes but do not require type ratings. The training should, however, be incorporated into type rating courses for aircraft that fly above 25,000 feet MSL if the pilot has not already received training in high-altitude flight. The training in this chapter does not encompass high-speed flight factors such as acceleration, G-forces, MACH, and turbine systems that do not apply to reciprocating engine and turboprop aircraft. Information on high-speed flight can be found in Chapter 2 of this AC.

**2. OUTLINE.** Additional information should be used to complement the training provided herein. The training outlined below, and explained in further detail in the remainder of this chapter, covers the minimum information needed by pilots to operate safely at high altitudes.

***a. Ground Training.***

(1) ***The High-Altitude Flight Environment.***

(i) Airspace.

(ii) FAR.

(2) ***Weather.***

(i) The atmosphere.

(ii) Winds and clear air turbulence.

(iii) Clouds and thuderstorms.

(iv) Icing.

(3) ***Flight Planning and Navigation.***

(i) Flight planning.

(ii) Weather charts.

(iii) Navigation.

(iv) Navaids.

(4) ***Physiological Training.***

(i) Respiration.

(ii) Hypoxia.

(iii) Effects of prolonged oxygen use.

(iv) Decompression sickness.

(v) Vision.

(vi) Altitude chamber (optional).

(5) ***High-Altitude Systems and Components.***

(i) Turbochargers.

(ii) Oxygen and oxygen equipment.

(iii) Pressurization systems.

(iv) High-altitude components.

(6) ***Aerodynamics and Performance Factors.***

(7) ***Emergencies.***

(i) Decompressions.

(ii) Turbocharger malfunction.

(iii) In-flight fire.

(iv) Flight into severe turbulence or thunderstorms.

***b. Flight Training.***

(1) ***Preflight Briefing.***

(2) ***Preflight Planning.***

(i) Weather briefing and considerations.

(ii) Course plotting.

(iii) Airplane Flight Manual review.

(iv) Flight plan.

(3) ***Preflight Inspection.***

(4) ***Runup, Takeoff, and Initial Climb.***

(5) ***Climb to High Altitude and Normal Cruise Operations While Operating Above 25,000 Feet MSL.***

(6) ***Emergencies.***

(i) Simulated rapid decompression.

(ii) Emergency descent.

(7) ***Planned Descents.***

(8) ***Shutdown Procedures.***

(9) ***Postflight Discussion.***

**3. GROUND TRAINING.** Thorough ground training should cover all aspects of high-altitude flight, including the flight environment, weather, flight planning and navigation, physiological aspects of high-altitude flight, systems and equipment, aerodynamics and performance, and high-altitude emergencies. The ground training should include the history and causes of some past accidents and incidents involving the topics included in paragraph 2. Accident reports are available from the NTSB and some aviation organizations.

**4. THE HIGH-ALTITUDE FLIGHT ENVIRONMENT.** For the purposes of FAR § 61.31(f), flight operations conducted above 25,000 feet are considered to be high altitude. However, the high-altitude environment itself begins below 25,000 feet. For example, flight levels (FL) are used at and above 18,000 feet (e.g., FL 180) to indicate levels of constant atmospheric pressure in relation to a reference datum of 29.92" Hg. Certain airspace designations and Federal Aviation Administration (FAA) requirements become effective at different altitudes. Pilots must be familiar with these elements before operating in each realm of flight.

***a. Airspace.*** Pilots of high-altitude aircraft are subject to three principle types of airspace at altitudes above 10,000 feet MSL. These are the Positive Control Area (PCA), which extends from FL 180 to FL 600; the Continental Control Area, which covers the continental United States above 14,500 feet MSL; and control zones that do not underlie the Continental Control Area, which extend upward from the surface and have no upper limit. (Other control zones terminate at the base of the Continental Control Area.)

***b. Federal Aviation Regulations.*** In addition to the training required by FAR § 61.31(f), pilots of high-altitude aircraft should be familiar with FAR Part 91 regulations that apply specifically to flight at high altitudes.

(1) FAR § 91.215 requires that all aircraft operating within the continental United States at and above 10,000 feet MSL be equipped with an operable transponder with Mode C capability (unless operating at or below 2,500 feet above ground level (AGL), below the PCA).

(2) FAR § 91.211(a) requires that the minimum flightcrew on civil aircraft of U.S. registry be provided with and use supplemental oxygen at cabin pressure altitudes above 12,500 feet MSL up to and including 14,000 feet MSL for that portion of the flight that is at those altitudes for more than 30 minutes. The required minimum flightcrew must be provided with and use supplemental oxygen at all times when operating an aircraft above 14,000 feet MSL. At cabin pressure altitudes above 15,000 feet MSL, all occupants of the aircraft must be provided with supplemental oxygen.

(3) FAR § 91.211(b) requires pressurized aircraft to have at least a 10-minute additional supply of supplemental oxygen for each occupant at flight altitudes above FL 250 in the event of a decompression. At flight altitudes above FL 350, one pilot at the controls of the airplane must wear and use an oxygen mask that is secured and sealed. The oxygen mask must supply oxygen at all times or must automatically supply oxygen when the cabin pressure altitude of the airplane exceeds 14,000 feet MSL. An exception to this regulation exists for two-pilot crews that operate at or below FL 410. One pilot does not need to wear and use an oxygen mask if both pilots are at the controls and each pilot has a quick donning type of oxygen mask that can be placed on the face with one hand from the ready position and be properly secured, sealed, and operational within 5 seconds. If one

pilot of a two-pilot crew is away from the controls, then the pilot that is at the controls must wear and use an oxygen mask that is secured and sealed.

(4) FAR § 91.121 requires that aircraft use an altimeter setting of 29.92 at all times when operating at or above FL 180.

(5) FAR § 91.135 requires that all flights within the PCA be conducted under instrument flight rules (IFR) in an aircraft equipped for IFR and flown by a pilot who is rated for instrument flight.

(6) FAR § 91.159 and § 91.179 specify cruising altitudes and flight levels for visual flight rules (VFR) and IFR flights, respectively. For VFR flights between FL 180 to FL 290 (except within the PCA where VFR flight is prohibited), odd flight levels plus 500 feet should be flown if the magnetic course is 0 to 179 , and even flight levels plus 500 feet should be flown if the magnetic course is 180 to 359 . VFR flights above FL 290 should be flown at 4,000 foot intervals beginning at FL 300 if the magnetic course is 0 to 179 and FL 320 if the magnetic course is 180 to 359 . For IFR flights in uncontrolled airspace between FL 180 and FL 290, odd flight levels should be flown if the magnetic course is 0 to 179 , and even flight levels should be flown if the magnetic course is 180 to 359 . IFR flights in uncontrolled airspace at or above FL 290 should be flown at 4,000 foot intervals beginning at FL 290 if the magnetic course is 0 to 179 and FL 310 if the magnetic course is 180 to 359 . When flying in the PCA, flight levels assigned by air traffic control (ATC) should be maintained.

5. **WEATHER.** Pilots should be aware of and recognize the meteorological phenomena associated with high altitudes and the effects of these phenomena on flight.

***a. The Atmosphere.*** The atmosphere is a mixture of gases in constant motion. It is composed of approximately 78 percent nitrogen, 21 percent oxygen, and 1 percent other gases. Water vapor is constantly being absorbed and released in the atmosphere which causes changes in weather. The three levels of the atmosphere where high-altitude flight may occur are the troposphere, which can extend from sea level to approximately FL 350 around the poles and up to FL 650 around the equator; the tropopause, a thin layer at the top of the troposphere that traps water vapor in the lower level; and the stratosphere, which extends from the tropopause to approximately 22 miles. The stratosphere is characterized by lack of moisture and a constant temperature of -55° C, while the temperature in the troposphere decreases at a rate of 2° C per 1,000 feet. Condensation trails, or contrails, are common in the upper levels of the troposphere and in the stratosphere. These cloud-like streamers that are generated in the wake of aircraft flying in clear, cold, humid air, form by water vapor from aircraft exhaust gases being added to the atmosphere causing saturation or supersaturation of the air. Contrails can also form aerodynamically by the pressure reduction around airfoils, engine nacelles, and propellers cooling the air to saturation.

***b. Atmospheric density*** in the troposphere decreases 50 percent at 18,000 feet. This means that at FL 180, the air contains only one-half the oxygen molecules as at sea level. Because the human body requires a certain amount of oxygen for survival, aircraft that fly at high altitudes must be equipped with some means of creating an artificial atmosphere, such as cabin pressurization.

*c. Winds.*

(1) The jet stream is a narrow band of high-altitude winds, near or in the tropopause, that results from large temperature contrasts over a short distance (typically along fronts) creating large pressure gradients aloft. The jet stream usually travels in an easterly direction between 50 and 200 K. The speed of the jet stream is greater in the winter than in the summer months because of greater temperature differences. It generally drops more rapidly on the polar side than on the equatorial side. In the mid-latitudes, the polar front jet stream is found in association with the polar front. This jet stream has a variable path, sometimes flowing almost due north and south.

(2) Because of its meandering path, the polar front jet stream is not found on most circulation charts. One almost permanent jet is a westerly jet found over the subtropics at 25° latitude about 8 miles above the surface. Low pressure systems usually form to the south of the jet stream and move northward until they become occluded lows which move north of the jet stream. Horizontal windshear and turbulence are frequently found on the northern side of the jet stream.

***d. Clear Air Turbulence (CAT).*** CAT is a meteorological phenomenon associated with high-altitude winds. This high-level turbulence occurs where no clouds are present and can take place at any altitude (normally above 15,000 feet AGL), although it usually develops in or near the jet stream where there is a rapid change in temperature. CAT is generally stronger on the polar side of the jet and is greatest during the winter months. CAT can be caused by windshear, convective currents, mountain waves, strong low pressures aloft, or other obstructions to normal wind flow. CAT is difficult to forecast because it gives no visual warning of its presence and winds can carry it far from its point of origin.

***e. Clouds and Thunderstorms.***

(1) Cirrus and cirriform clouds are high-altitude clouds that are composed of ice crystals. Cirrus clouds are found in stable air above 30,000 feet in patches or narrow bands. Cirriform clouds, such as the white clouds in long bands against a blue background known as cirrostratus clouds, generally indicate some type of system below. Cirrostratus clouds form in stable air as a result of shallow convective currents and also may produce light turbulence. Clouds with extensive vertical development (e.g., towering cumulus and cumulonimbus clouds) indicate a deep layer of unstable air and contain moderate to heavy turbulence with icing. The bases of these clouds are found at altitudes associated with low to middle clouds but their tops can extend up to 60,000 feet or more.

(2) Cumulonimbus clouds are thunderstorm clouds that present a particularly severe hazard to pilots and should be circumnavigated if possible. Hazards associated with cumulonimbus clouds include embedded thunderstorms, severe or extreme turbulence, lightning, icing, and dangerously strong winds and updrafts.

***f. Icing.*** Icing at high altitudes is not as common or extreme as it can be at low altitudes. When it does occur, the rate of accumulation at high altitudes is generally slower than at low altitudes. Rime ice is generally more common at high altitudes than clear ice, although clear ice is possible. Despite the composition of cirrus clouds, severe icing is generally not a problem although it can occur in some detached cirrus. It is more common in tops of tall cumulus buildups, anvils, and over mountainous regions. Many airplanes that operate above 25,000 feet are equipped with deice or anti-ice systems, reducing even further the dangers of icing.

## 6. FLIGHT PLANNING AND NAVIGATION.

### *a. Flight Planning.*

(1) Careful flight planning is critical to safe high-altitude flight. Consideration must be given to power settings, particularly on takeoff, climb, and descent to assure operation in accordance with the manufacturer's recommendations. Fuel management, reporting points, weather briefings (not only thunderstorms, the freezing level, and icing at altitude but at all levels and destinations, including alternates, that may affect the flight), direction of flight, airplane performance charts, high speed winds aloft, and oxygen duration charts must also be considered. When possible, additional oxygen should be provided to allow for emergency situations. Breathing rates increase under stress and extra oxygen could be necessary.

(2) Flight planning should take into consideration factors associated with altitudes that will be transited while climbing to or descending from the high altitudes (e.g., airspeed limitations below 10,000 feet MSL, airspace, and minimum altitudes). Westward flights should generally be made away from the jet stream to avoid the strong headwind, and eastward flights should be made in the jet stream when possible to increase groundspeed. Groundspeed checks are particularly important in high-altitude flight. If fuel runs low because of headwinds or poor flight planning, a decision to fly to an alternate airport should be made as early as possible to allow time to replan descents and advise ATC.

*b. Knowledge of Aircraft.* Complete familiarity with the aircraft systems and limitations is extremely important. For example, many high-altitude airplanes feed from only one fuel tank at a time. If this is the case, it is important to know the fuel consumption rate to know when to change tanks. This knowledge should be made part of the preflight planning and its accuracy confirmed regularly during the flight.

*c. Gradual Descents.* Gradual descents from high altitudes should be planned in advance to prevent excessive engine cooling and provide passenger comfort. The manufacturer's recommendations found in the Airplane Flight Manual should be complied with, especially regarding descent power settings to avoid stress on the engines. Although most jets can descend rapidly at idle power, many turboprop and light twin airplanes require some power to avoid excessive engine cooling, cold shock, and metal fatigue. ATC does not always take aircraft type into consideration when issuing descent instructions. It is the pilot's responsibility to fly the airplane in the safest manner possible. Cabin rates of descent are particularly important and should generally not exceed 500 or 600 feet per minute. Before landing, cabin pressure should be equal to ambient pressure or inner ear injury can result. If delays occur en route, descents should be adjusted accordingly.

*d. Weather Charts.* Before beginning a high-altitude flight, all weather charts should be consulted, including those designed for low levels. Although high-altitude flight may allow a pilot to overfly adverse weather, low altitudes must be transited on arrival, departure, and in an emergency situation that may require landing at any point en route.

*e. Types of Weather Charts.* Weather charts that provide information on high-altitude weather include Constant Pressure Charts, which provide information on pressure systems, temperature, winds, and temperature/dewpoint spread at the 850 millibar (mb), 700 mb, 500 mb, 300 mb, and 200 mb levels (5 charts are issued every 12 hours). Prognostic Charts forecast winds, temperature, and expected movement of weather over the 6-hour valid time of the chart. Observed Tropopause Charts provide jet stream, turbulence, and temperature-wind-pressure reportings at the tropopause over each station. Tropopause Wind Prognostic Charts and Tropopause Height Vertical Windshear Charts are helpful in determining jet stream patterns and the presence of CAT and windshear.

*f.* ***Windshear.*** Windshear is indicated by dashed lines on Tropopause Height Vertical Windshear Charts. Horizontal wind changes of 40 K within 150 NM, or vertical windshear of 6 K or greater per 1,000 feet usually indicate moderate to severe turbulence and should be avoided. Pilot reports (PIREPs) are one of the best methods of receiving timely and accurate reports on icing and turbulence at high altitudes.

***g. Navigation.*** Specific charts have been designed for flight at FL 180 and above. Enroute high-altitude charts delineate the jet route system, which consists of routes established from FL 180 up to and including FL 450. The VOR airways established below FL 180 found on low-altitude charts must not be used at FL 180 and above. High-altitude jet routes are an independent matrix of airways, and pilots must have the appropriate enroute high-altitude charts before transitioning to the flight levels.

***h. Jet Routes.*** Jet routes in the U.S. are predicated solely on VOR or VORTAC navigation facilities, except in Alaska where some are based on L/MF navigation aids. All jet routes are identified by the letter "J" and followed by the airway number.

*i.* ***Reporting Points.*** Reporting points are designated for jet route systems and must be used by flights using the jet route unless otherwise advised by ATC. Flights above FL 450 may be conducted on a point-to-point basis, using the facilities depicted on the enroute high-altitude chart as navigational guidance. Random and fixed Area Navigation (RNAV) Routes are also used for direct navigation at high altitudes and are based on area navigation capability between waypoints defined in terms of latitude/longitude coordinates, degree-distance fixes, or offsets from established routes or airways at a specified distance and direction. Radar monitoring by ATC is required on all random RNAV routes.

*j.* ***Point-to-Point Navigation.*** In addition to RNAV, many high-altitude airplanes are equipped with point-to-point navigation systems for high-altitude en route flight. These include LORAN-C, OMEGA, Inertial Navigation System, and Doppler Radar. Further information about these and additional navigation systems are available in the Airman's Information Manual.

*k.* ***Navaids.*** VOR, DME, and TACAN depicted on high-altitude charts are designated as class H navaids, signifying that their standard service volume is from 1,000 feet AGL up to and including 14,500 AGL at radial distances out to 40 NM; from 14,500 feet AGL up to and including 60,000 feet AGL at radial distances out to 100 NM; and from 18,000 feet AGL up to and including 45,000 feet AGL at radial distances out to 130 NM. Ranges of NDB service volumes are the same at all altitudes.

**7. PHYSIOLOGICAL TRAINING.** To ensure safe flights at high altitudes, pilots of high-altitude aircraft must understand the physiological effects of high-altitude flight.

Additional physiological training information, including locations and application procedures for attending an altitude chamber, can be found in paragraph 8 of this chapter. Although not required, altitude chamber training is highly recommended for all pilots.

*a. **Respiration*** is the exchange of gases between the organism and its environment. In humans, external respiration is the intake of oxygen from the atmosphere by the lungs and the elimination of some carbon dioxide from the body into the surrounding atmosphere. Each breath intake is comprised of approximately 21 percent oxygen, which is absorbed into the bloodstream and carried by the blood throughout the body to burn food material and to produce heat and kinetic energy. The partial pressure of oxygen forces oxygen through air sacs (alveoli), located at the end of each of the smaller tubes that branches out from the bronchial tubes and lungs, into the bloodstream. Other gases contained in the lungs reduce the partial pressure of oxygen entering the air sacs to about 102 mm Hg at ground level, which is approximately 21 percent of the total atmospheric pressure.

*b. **The human body*** functions normally in the atmospheric area extending from sea level to 12,000 feet MSL. In this range, brain oxygen saturation is at a level that allows for normal functioning. (Optimal functioning is 96 percent saturation. At 12,000 feet, brain oxygen saturation is approximately 87 percent which begins to approach a level that could affect human performance. Although oxygen is not required below 12,500 feet MSL, its use is recommended when flying above 10,000 feet MSL during the day and above 5,000 feet MSL at night when the eyes become more sensitive to oxygen deprivation.)

*c. **Although minor physiological problems,*** such as middle ear and sinus trapped gas difficulties, can occur when flying below 12,000 feet, shortness of breath, dizziness, and headaches will result when an individual ascends to an altitude higher than that to which his or her body is acclimated. From 12,000 to 50,000 feet MSL, atmospheric pressure drops by 396 mm Hg. This area contains less partial pressure of oxygen which can result in problems such as trapped or evolved gases within the body. Flight at and above 50,000 feet MSL requires sealed cabins or pressure suits.

*d. **Hypoxia*** is a lack of sufficient oxygen in the body cells or tissues caused by an inadequate supply of oxygen, inadequate transportation of oxygen, or inability of the body tissues to use oxygen. A common misconception among many pilots who are inexperienced in high-altitude flight operations and who have not been exposed to physiological training is that it is possible to recognize the symptoms of hypoxia and to take corrective action before becoming seriously impaired. While this concept may be appealing in theory, it is both misleading and dangerous for an untrained crewmember. Symptoms of hypoxia vary from pilot to pilot, but one of the earliest effects of hypoxia is impairment of judgment. Other symptoms can include one or more of the following:

(1) Behavioral changes (e.g., a sense of euphoria).

(2) Poor coordination.

(3) Discoloration at the fingernail beds (cyanosis).

(4) Sweating.

(5) Increased breathing rate, headache, sleepiness, or fatigue.

(6) Loss or deterioration of vision.

(7) Light-headedness or dizzy sensations and listlessness.

(8) Tingling or warm sensations.

***e. While other significant effects of hypoxia*** usually do not occur in a healthy pilot in an unpressurized aircraft below 12,000 feet, there is no assurance that this will always be the case. The onset of hypoxic symptoms may seriously affect the safety of flight and may well occur even in short periods of exposure to altitudes from 12,000 to 15,000 feet. The ability to take corrective measures may be totally lost in 5 minutes at 22,000 feet. However, that time would be reduced to only 18 seconds at 40,000 feet and the crewmember may suffer total loss of consciousness soon thereafter. A description of the four major hypoxia groups and the recommended methods to combat each follows.

(1) ***Hypoxic (Altitude) Hypoxia.*** Altitude hypoxia poses the greatest potential physiological hazard to a flight crewmember while flying in the high-altitude environment. This type of hypoxia is caused by an insufficient partial pressure of oxygen in the inhaled air resulting from reduced oxygen pressure in the atmosphere at altitude. If a person is able to recognize the onset of hypoxic symptoms, immediate use of supplemental oxygen will combat hypoxic hypoxia within seconds. Oxygen systems should be checked periodically to ensure that there is an adequate supply of oxygen and that the system is functioning properly. This check should be performed frequently with increasing altitude. If supplemental oxygen is not available, an emergency descent to an altitude below 10,000 feet should be initiated.

(2) ***Histotoxic Hypoxia.*** This is the inability of the body cells to use oxygen because of impaired cellular respiration. This type of hypoxia, caused by alcohol or drug use, cannot be corrected by using supplemental oxygen because the uptake of oxygen is impaired at the tissue level. The only method of avoiding this type of hypoxia is to abstain, before flight, from alcohol or drugs that are not approved by a flight surgeon or an aviation medical examiner.

(3) ***Hypemic (Anemic) Hypoxia.*** This type of hypoxia is defined as a reduction in the oxygen-carrying capacity of the blood. Hypemic hypoxia is caused by a reduction in circulating red blood cells (hemoglobin) or contamination of blood with gases other than oxygen as a result of anemia, carbon monoxide poisoning, or excessive smoking. Pilots should take into consideration the effect of smoking on altitude tolerance when determining appropriate cabin pressures. If heavy smokers are among the crew or passengers, a lower cabin altitude should be set because apparent altitudes for smokers are generally much higher than actual altitudes. For example, a smoker's apparent altitude at sea level is approximately 7,000 feet. Twenty thousand feet actual altitude for a nonsmoker would be equivalent to an apparent altitude of 22,000 feet for a smoker. The smoker is thus more susceptible to hypoxia at lower altitudes than the nonsmoker. Hypemic hypoxia is corrected by locating and eliminating the source of the contaminating gases. A careful preflight of heating systems and exhaust manifold equipment is mandatory. Also, cutting down on smoking would minimize the onset of this type of hypoxia. If symptoms are recognized, initiate use of supplemental oxygen and/or descend to an altitude below 10,000 feet. If symptoms persist, ventilate the cabin and land as soon as possible because the symptoms may be indicative of

carbon monoxide poisoning and medical attention should be sought.

(4) ***Stagnant Hypoxia.*** This is an oxygen deficiency in the body resulting from poor circulation of the blood because of a failure of the circulatory system to pump blood (and oxygen) to the tissues. Evidence of coronary artery disease is grounds for immediate denial or revocation of a medical certificate. In flight, this type of hypoxia can sometimes be caused by positive pressure breathing for long periods of time or excessive G-forces.

***f. Effective Performance Time (EPT) or Time of Useful Consciousness (TUC)*** is the amount of time in which a person is able to effectively or adequately perform flight duties with an insufficient supply of oxygen. EPT decreases with altitude, until eventually coinciding with the time it takes for blood to circulate from the lungs to the head usually at an altitude above 35,000 feet. Table 1 shows the TUC (shown as average TUC) at various altitudes.

Table 1. Times Of Useful Consciousness At Various Altitudes

| Altitude (Feet) | Sitting Quietly | Moderate Activity |
|---|---|---|
| 22,000 | 10 minutes | 5 minutes |
| 25,000 | 5 minutes | 3 minutes |
| 30,000 | 1 minute | 45 seconds |
| 35,000 | 45 seconds | 30 seconds |
| 40,000 | 25 seconds | 18 seconds |

***g. Other factors that determine EPT*** are the rate of ascent (faster rates of ascent result in shorter EPT's), physical activities (exercise decreases EPT's), and day-to-day factors such as physical fitness, diet, rest, prescription drugs, smoking, and illness. Altitude chamber experiments found a significantly longer TUC for nonsmoker pilots who exercise and watch their diet than for pilots who smoke and are not physically fit.

***h. Prolonged oxygen use*** can also be harmful to human health. One hundred percent aviation oxygen can produce toxic symptoms if used for extended periods of time. The symptoms can consist of bronchial cough, fever, vomiting, nervousness, irregular heart beat, and lowered energy. These symptoms appeared on the second day of breathing 90 percent oxygen during controlled experiments. It is unlikely that oxygen would be used long enough to produce the most severe of these symptoms in any aviation incidence. However, prolonged flights at high altitudes using a high concentration of oxygen can produce some symptoms of oxygen poisoning such as infection or bronchial irritation. The sudden supply of pure oxygen following a decompression can often aggravate the symptoms of hypoxia. Therefore, oxygen should be taken gradually, particularly when the body is already suffering from lack of oxygen, to build up the supply in small doses. If symptoms of oxygen poisoning develop, high concentrations of oxygen should be avoided until the symptoms completely disappear.

***i. When nitrogen is inhaled,*** it dilutes the air we breathe. While most nitrogen is exhaled from the lungs along with carbon dioxide, some nitrogen is absorbed by the body. The nitrogen absorbed into the body tissues does not normally present any problem because it is carried in a liquid state. If the ambient surrounding atmospheric pressure lowers drastically, this nitrogen could change from a liquid and return to its gaseous state in the form of bubbles. These evolving and expanding gases in the body are known as decompression sickness and are divided into two groups.

(1) *Trapped Gas.* Expanding or contracting gas in certain body cavities during altitude changes can result in abdominal pain, toothache, or pain in ears and sinuses if the person is unable to equalize the pressure changes. Above 25,000 feet, distention can produce particularly severe gastrointestinal pain.

(2) *Evolved Gas.* When the pressure on the body drops sufficiently, nitrogen comes out of solution and forms bubbles which can have adverse effects on some body tissues. Fatty tissue contains more nitrogen than other tissue; thus making overweight people more susceptible to evolved gas decompression sicknesses.

(i) SCUBA diving will compound this problem because of the compressed air used in the breathing tanks. After SCUBA diving, a person who flies in an aircraft to an altitude of 8,000 feet would experience the same effects as a nondiver flying at 40,000 feet unpressurized. The recommended waiting period before going to flight altitudes of 8,000 feet is at least 12 hours after nondecompression stop diving (diving which does not require a controlled ascent), and 24 hours after decompression stop diving (diving which requires a controlled ascent). For flight altitudes above 8,000 feet, the recommended waiting time is at least 24 hours after any SCUBA diving.

(ii) The bends, also known as caisson disease, is one type of evolved gas decompression sickness and is characterized by pain in and around the joints. The term bends is used because the resultant pain is eased by bending the joints. The pain gradually becomes more severe, can eventually become temporarily incapacitating, and can result in collapse. The chokes refers to a decompression sickness that manifests itself through chest pains and burning sensations, a desire to cough, possible cyanosis, a sensation of suffocation, progressively shallower breathing and, if a descent is not made immediately, collapse and unconsciousness. Paresthesia is a third type of decompression sickness, characterized by tingling, itching, a red rash, and cold and warm sensations, probably resulting from bubbles in the central nervous system (CNS). CNS disturbances can result in visual deficiencies such as illusionary lines or spots, or a blurred field of vision. Some other effects of CNS disturbances are temporary partial paralysis, sensory disorders, slurred speech, and seizures.

***j. Shock*** can often result from decompression sicknesses as a form of body protest to disrupted circulation. Shock can cause nausea, fainting, dizziness, sweating, and/or loss of consciousness. The best treatment for decompression sickness is descent to a lower altitude and landing. If conditions persist after landing, recompression chambers can be located through an aviation medical examiner.

***k. Vision*** has a tendency to deteriorate with altitude. A reversal of light distribution at high altitudes (bright clouds below the airplane and darker, blue sky above) can cause a glare inside the cockpit. Glare effects and deteriorated vision are enhanced at night when the body becomes more susceptible to hypoxia. Night vision can begin to deteriorate at cabin pressure altitudes as low as 5,000 feet. In addition, the empty visual field caused by cloudless, blue skies during the day can cause inaccuracies when judging the speed, size, and distance of other aircraft. Sunglasses are recommended to minimize the intensity of the sun's ultraviolet rays at high altitudes.

**8. ADDITIONAL PHYSIOLOGICAL TRAINING.** There are no specific requirements in FAR Part 91 or Part 125 for physiological training. However, in addition to the high-altitude training required by FAR § 61.31(f), which should include the physiological training outlined in this chapter, FAR Parts 121 and 135 require flight crewmembers that serve in operations above 25,000 feet to receive training in specified subjects of aviation physiology. None of the requirements includes altitude chamber training. The U.S. military services require its flight crewmembers to complete both initial and refresher physiological training, including instruction in basic aviation physiology and altitude chamber training. Other U.S. Government agencies, such as the National Aviation and Space Administration and FAA, also require their flight personnel who operate pressurized aircraft in the high-altitude flight environment to complete similar training. Although most of the subject material normally covered in physiological training concerns problems associated with reduced atmospheric pressure at high-flight altitudes, other equally important subjects are covered as well. Such subjects of aviation physiology as vision, disorientation, physical fitness, stress, and survival affect flight safety and are normally presented in a good training program.

*a. Physiological training programs* are offered at locations across the United States (Table 2) for pilots who are interested in learning to recognize and overcome vertigo, hypoxia, hyperventilation, etc., during flight. Trainees who attend these programs will be given classroom lectures, a high-altitude "flight" in an altitude chamber, and time in a jet aircraft cockpit spatial disorientation training device at some of the military bases that offer the course.

*b. Persons who wish to take this training* must be at least 18 years of age, hold a current FAA Airman Medical Certificate, and must not have a cold or any other significant health problem when enrolling for the course.

*c. Applications for physiological training* may be obtained at any FAA Flight Standards District Office. Persons who wish to enroll should send a completed application and payment (minimal fee for the course is $20) to the Mike Monroney Aeronautical Center, General Accounting Branch, AAC-23B, Box 25082, Oklahoma City, Oklahoma 73125.

*d. Within 30 to 60 days,* the applicant will be notified of the time and place of training.

Table 2. List of Training Locations

| | | |
|---|---|---|
| Aeronautical Center, OK | Fairchild AFB, WA | Peterson AFB, CO |
| Andrews AFB, MD | Jacksonville NAS, FL | Point Mugu NMC, CA |
| Barbers Point NAS, HI | Laughlin AFB, TX | Reese AFB, TX |
| Beale AFB, TX | Lemoore NAS, CA | San Diego NAS, CA |
| Brooks AFB, TX | Little Rock AFB, AR | Sheppard AFB, TX |
| Brunswick NAS, ME | MacDill AFB, CA | Vance AFB, OK |
| Cherry Point MCAS, NC | Mather AFB, CA | Whidbey Island NAS, WA |
| Columbus AFB, MS | NASA Johnson Space Center, TX | Williams AFB, AZ |
| Edwards AFB, CA | Norfolk NAS, VA | Wright AFB, AZ |
| Ellsworth AFB, CA | Patuxent River NAS, MD | Wright-Patterson AFB, OH |
| El Toro MCAS, CA | Pease AFB, NH | |

**9. HIGH-ALTITUDE SYSTEMS AND EQUIPMENT.** Several systems and equipment are unique to aircraft that fly at high altitudes, and pilots should be familiar with their operation before using them. Before any flight, a pilot should be familiar with all the systems on the aircraft to be flown.

***a. Turbochargers.*** Most light piston engine airplanes that fly above 25,000 feet MSL are turbocharged. Turbochargers compress air in the carburetor or cylinder intake by using exhaust gases from an engine-driven turbine wheel. The increased air density provides greater power and improved performance. Light aircraft use one of two types of turbocharging systems. The first is the normalizer system, which allows the engine to develop sea level pressure from approximately 29 inches of manifold pressure up to a critical altitude (generally between 14,000-16,000 feet MSL). The supercharger system is a more powerful system which allows the engine to develop higher than sea level pressure (up to 60 inches of manifold pressure) up to a critical altitude. To prevent overboosting at altitudes below the critical altitude, a waste gate is installed in the turbocompressor system to release unnecessary gases. The waste gate is a damper-like device that controls the amount of exhaust that strikes the turbine rotor. As the waste gate closes with altitude, it sends more gases through the turbine compressor, causing the rotor to spin faster. This allows the engine to function as if it were maintaining sea level or, in the case of a supercharger, above sea level manifold pressure. The three principle types of waste gate operations are manual, fixed, and automatic.

(1) *Manual Waste Gate.* Manual waste gate systems are common in older aircraft but have been discontinued due to the additional burden on the pilot. Waste gates were often left closed on takeoff or open on landing, resulting in an overboost that could harm the engine.

(2) ***Fixed Waste Gate.*** Fixed waste gates pose less of a burden on the pilot, but the pilot must still be careful not to overboost the engine, especially on takeoff, initial climb, and on cold days when the air is especially dense. This type of waste gate remains in the same position during all engine operations, but it splits the exhaust flow allowing only partial exhaust access to the turbine. The pilot simply controls manifold pressure with smooth, slow application of the throttle to control against overboost. If overboost does occur, a relief valve on the intake manifold protects the engine from damage. This is not a favorable system due to fluctuations in manifold pressure and limited additional power from the restricted control over the exhaust flow. In addition, the compressor can produce excessive pressure and cause overheating.

(3) ***Automatic Waste Gate.*** Automatic waste gates operate on internal pressure. When internal pressure builds towards an overboost, the waste gate opens to relieve pressure, keeping the engine within normal operating limits regardless of the air density.

(i) The pressure-reference automatic waste gate system maintains the manifold pressure set by the throttle. Engine oil pressure moves the waste gate to maintain the appropriate manifold pressure, thus reducing the pilot's workload and eliminating the possibility of overboost. If the airplane engine is started up and followed by an immediate takeoff, cold oil may cause a higher than intended manifold pressure. Allow the oil to warm up and circulate throughout the system before takeoff.

(ii) The density-reference waste gate system is controlled by compressor discharge air. A density controller holds a given density of air by automatically adjusting manifold pressure as airspeed, ambient pressure, temperature, altitude, and other variables change.

*b. Turbocharged engines* are particularly temperature sensitive. Manufacturers often recommend increasing the fuel flow during climbs to prevent overheating. It is also important to cool the engine after landing. Allowing the engine to idle for approximately 1 minute before shutting it down permits engine oil to flow through the system, cooling the engine while simultaneously cooling and lubricating the turbocharger.

*c. Most high-altitude airplanes* come equipped with some type of fixed oxygen installation. If the airplane does not have a fixed installation, portable oxygen equipment must be readily accessible during flight. The portable equipment usually consists of a container, regulator, mask outlet, and pressure gauge. A typical 22 cubic-foot portable container will allow four people enough oxygen to last approximately 1.5 hours at 18,000 feet MSL. Aircraft oxygen is usually stored in high pressure system containers of 1,800-2,200 pounds per square inch (PSI). The container should be fastened securely in the aircraft before flight. When the ambient temperature surrounding an oxygen cylinder decreases, pressure within that cylinder will decrease because pressure varies directly with temperature if the volume of a gas remains constant. Therefore, if a drop in indicated pressure on a supplemental oxygen cylinder is noted, there is no reason to suspect depletion of the oxygen supply, which has simply been compacted due to storage of the containers in an unheated area of the aircraft. High pressure oxygen containers should be marked with the PSI tolerance (i.e., 1,800 PSI) before filling the container to that pressure. The containers should be supplied with aviation oxygen only, which is 100 percent pure oxygen. Industrial oxygen is not intended for breathing and may contain impurities, and medical oxygen contains water vapor that can freeze in the regulator when exposed to cold temperatures. To assure safety, oxygen system periodic inspection and servicing should be done at FAA certificated stations found at some fixed base operations and terminal complexes.

*d. Regulators and masks* work on continuous flow, diluter demand, or on pressure demand systems. The continuous flow system supplies oxygen at a rate that may either be controlled by the user or controlled automatically on some regulators. The mask is designed so the oxygen can be diluted with ambient air by allowing the user to exhale around the face piece, and comes with a rebreather bag which allows the individual to reuse part of the exhaled oxygen. The pilots' masks sometimes allow greater oxygen flow than passengers' masks, so it is important that the pilots use the masks that are indicated for them. Although certificated up to 41,000 feet, very careful attention to system capabilities is required when using continuous flow oxygen systems above 25,000 feet.

*e. Diluter demand and pressure demand systems* supply oxygen only when the user inhales through the mask. An automix lever allows the regulators to automatically mix cabin air and oxygen or supply 100 percent oxygen, depending on the altitude. The demand mask provides a tight seal over the face to prevent dilution with outside air and can be used safely up to 40,000 feet. Pilots who fly at those altitudes should not have beards and moustaches because air can easily seep in through the border of the mask. Pressure demand regulators also create airtight and oxygen-tight seals but they also provide a positive pressure application of oxygen to the mask face piece which allows the user's lungs to be pressurized with oxygen. This feature makes pressure demand regulators safe at altitudes above 40,000 feet.

*f. Pilots should be aware of the danger* of fire when using oxygen. Materials that are nearly fireproof in ordinary air may be susceptible to burning in oxygen. Oils and greases may catch fire if exposed to oxygen and, therefore, cannot be used for sealing the valves and fittings of oxygen equipment. Smoking during any kind of oxygen equipment use must also be strictly forbidden.

*g. Surplus oxygen equipment* must be inspected and approved by a certified FAA inspection station before being used. Before each flight, the pilot should thoroughly inspect and test all oxygen equipment. The inspection should be accomplished with clean hands and should include a visual inspection of the mask and tubing for tears, cracks, or deterioration; the regulator for valve and lever condition and positions; oxygen quantity; and the location and functioning of oxygen pressure gauges, flow indicators and connections. The mask should be donned and the system should be tested. After any oxygen use, verify that all components and valves are shut off.

*h. Cabin pressurization* is the compression of air in the aircraft cabin to maintain a cabin altitude lower than the actual flight altitude. Because of the ever-present possibility of decompression, supplemental oxygen is still required. Pressurized aircraft meeting specific requirements of FAR Part 23 or Part 25 have cabin altitude warning systems which are activated at 10,000 feet. Pressurized aircraft meeting the still more stringent requirements of FAR Part 25 have automatic passenger oxygen mask dispensing devices which activate before exceeding 15,000 feet cabin altitude.

*i. Pressurization in most light aircraft* is sent to the cabin from the turbocharger's compressor or from an engine-driven pneumatic pump. The flow of compressed air into the cabin is regulated by an outflow valve which keeps the pressure constant by releasing excess pressure into the atmosphere. The cabin altitude can be manually selected and is monitored by a gauge which indicates the pressure difference between the cabin and ambient altitudes. The rate of change between these two pressures is automatically controlled with a manual backup control.

*j. Each pressurized aircraft* has a determined maximum pressure differential, which is the maximum differential between cabin and ambient altitudes that the pressurized section of the aircraft can support. The pilot must be familiar with these limitations, as well as the manifold pressure settings recommended for various pressure differentials. Some aircraft have a negative pressure relief valve to equalize pressure in the event of a sudden decompression or rapid descent to prevent the cabin pressure from becoming higher than the ambient pressure.

*k. Reducing exposure to low barometric pressure* lowers the occurrence of decompression sickness and the need for an oxygen mask is eliminated as a full time oxygen source above certain altitudes. Many airplanes are equipped with automatic visual and aural warning systems that indicate an unintentional loss of pressure.

*l. Technology* is continuously improving flight at high altitudes through the development of new devices and the improvement of existing systems. One such example is the pressurized magneto. Thin air at high altitudes makes the unpressurized magneto susceptible to crossfiring. The high tension pressurized system is composed of sealed caps and plugs that keep the electrodes contained within the body. A pressure line extends directly from the turbodischarger to the magneto. Pressurized magnetos perform better at high altitudes where low pressure and cold atmosphere have a detrimental effect on electrical conductivity. Flight above 14,000 feet with an unpressurized magneto should be avoided because of its higher susceptibility to arcing.

***m. Another airplane component recommended for flight at high altitudes*** is the dry vacuum pump. Engine-driven wet vacuum pumps cannot create sufficient vacuum to drive the gyros in the low density found at high altitudes. Furthermore, gyros and rubber deicing boots can be ruined by oil contamination from the wet pump system, which uses engine oil for lubrication and cooling. Dry vacuum pumps are lightweight, self-lubricating systems that eliminate oil contamination and cooling problems. These pumps can power either a vacuum or pressure pneumatic system, allowing them to drive the gyros, deice boots, and pressurize the door seals.

**10. AERODYNAMICS AND PERFORMANCE FACTORS.** Thinner air at high altitudes has a significant impact on an airplane's flying characteristics because surface control effects, lift, drag, and horsepower are all functions of air density.

***a. The reduced weight of air*** moving over control surfaces at high altitudes decreases their effectiveness. As the airplane approaches its absolute altitude, the controls become sluggish, making altitude and heading difficult to maintain. For this reason, most airplanes that fly at above 25,000 feet are equipped with an autopilot.

***b. A determined weight of air*** is used by the engine for producing an identified amount of horsepower through internal combustion. For a given decrease of air density, horsepower decreases at a higher rate which is approximately 1.3 times that of the corresponding decrease in air density.

***c. For an airplane to maintain level flight,*** drag and thrust must be equal. Because density is always greatest at sea level, the velocity at altitude given the same angle of attack will be greater than at sea level, although the indicated air speed (IAS) will not change. Therefore, an airplane's TAS increases with altitude while its IAS remains constant. In addition, an airplane's rate of climb will decrease with altitude.

**11. EMERGENCIES AND IRREGULARITIES AT HIGH ALTITUDES.** All emergency procedures in the Airplane Flight Manual should be reviewed before flying any airplane, and that manual should be readily accessible during every flight. A description of some of the most significant high-altitude emergencies and remedial action for each follows.

***a. Decompression*** is defined as the inability of the aircraft's pressurization system to maintain its designed pressure schedule. Decompression can be caused by a malfunction of the system itself or by structural damage to the aircraft. A decompression will often result in cabin fog because of the rapid drop in temperature and the change in relative humidity. A decompression will also affect the human body. Air will escape from the lungs through the nose and mouth because of a sudden lower pressure outside of the lungs. Differential air pressure on either side of the eardrum should clear automatically. Exposure to windblast and extremely cold temperatures are other hazards the human body may face with a decompression.

***b. Decompression of a small cabin volume pressurized aircraft*** is more critical than a large one, given the same size hole or conditions, primarily because of the difference in cabin volumes. Table 3 is a comparison of cabin volume ratios between several large transport airplanes and some of the more popular general aviation turbojet airplanes in current use. Table 3 shows that, under the same conditions, a typical small pressurized aircraft can be expected to decompress on the order of 10 to 200 times as fast as a large aircraft. The B-747/Learjet comparison is an extreme example in that the human response, TUC, and the protective equipment necessary are the same. Actual decompression times are difficult to calculate due to many variables involved (e.g., the type of failure, differential pressure, cabin volume, etc.). However, it is more probable that the crew of the small aircraft will have less time in which to take lifesaving actions.

(1) An explosive decompression is a change in cabin pressure faster than the lungs can decompress. Most authorities consider any decompression which occurs in less than 0.5 seconds as explosive and potentially dangerous. This type of decompression is more likely to occur in small volume pressurized aircraft than in large pressurized aircraft and often results in lung damage. To avoid potentially dangerous flying debris in the event of an explosive decompression, all loose items such as baggage and oxygen cylinders should be properly secured.

Table 3. Aircraft Cabin Volume Ratios

| Aircraft Type | Cabin Volumes in Cubic Feet | Ratio |
|---|---|---|
| DC-9 vs CE-650 | 5,840 vs 576 | 10:1 |
| B-737 vs LR-55 | 8,010 vs 502 | 16:1 |
| B-727 vs NA-265 | 9,045 vs 430 | 21:1 |
| L-1011 vs G-1159 | 35,000 vs 1,850 | 19:1 |
| B-747 vs Learjet | 59,000 vs 265 | 223:1 |

Data Source: Physiological Considerations and Limitations in the High-altitude Operation of Small-Volume Pressurized Aircraft. E. B. McFadden and D. de Steigner, Federal Aviation Administration (FAA) Civil Aeromedical Institute (CAMI).

(2) A rapid decompression is a change in cabin pressure where the lungs can decompress faster than the cabin. The risk of lung damage is significantly reduced in this decompression as compared with an explosive decompression.

(3) Gradual or slow decompression is dangerous because it may not be detected. Automatic visual and aural warning systems generally provide an indication of a slow decompression.

(4) Recovery from all types of decompression is similar. Oxygen masks should be donned, and a rapid descent initiated as soon as possible to avoid the onset of hypoxia. Although top priority in such a situation is reaching a safe altitude, pilots should be aware that cold-shock in piston engines can result from a high-altitude rapid descent, causing cracked cylinders or other engine damage. The time allowed to make a recovery to a safe altitude before loss of useful consciousness is, of course, much less with an explosive than with a gradual decompression.

***c. Increased oil temperature, decreased oil pressure, and a drop in manifold pressure*** could indicate a turbocharger malfunction or a partial or complete turbocharger failure. The consequences of such a malfunction or failure are twofold. The airplane would not be capable of sustaining altitude without the additional power supplied by the turbocharging system. The loss in altitude in itself would not create a significant problem, weather and terrain permitting, but ATC must be notified of the descent. A more serious problem associated with a failed turbocharger would be loss of cabin pressurization if the pressurization system is dependent on the turbocharger compressor. Careful monitoring of pressurization levels is essential during the descent to avoid the onset of hypoxia from a slow decompression.

***d. Another potential problem associated with turbochargers*** is fuel vaporization. Engine-driven pumps that pull fuel into the intake manifold are susceptible to vapor lock at high altitudes. Most high-altitude aircraft are equipped with tank-mounted boost pumps to feed fuel to the engine-driven pump under positive pressure. These pumps should be turned on if fuel starvation occurs as a result of vapor lock.

***e. Because of the highly combustible composition of oxygen,*** an immediate descent to an altitude where oxygen is not required should be initiated if a fire breaks out during a flight at high altitude. The procedures in the Airplane Flight Manual should be closely adhered to.

***f. Flight through thunderstorm activity or known severe turbulence should be avoided,*** if possible. When flight through severe turbulence is anticipated and/or unavoidable, the following procedures are highly recommended:

(1) Airspeed is critical for any type of turbulent air penetration. Use the Airplane Flight Manual recommended turbulence penetration target speed or, if unknown, an airspeed below maneuvering speed. Use of high airspeeds can result in structural damage and injury to passengers and crewmembers. Severe gusts may cause large and rapid variations in indicated airspeed. Do not chase airspeed.

(2) Penetration should be at an altitude that provides adequate maneuvering margins in case severe turbulence is encountered to avoid the potential for catastrophic upset.

(3) If severe turbulence is penetrated with the autopilot on, the altitude hold mode should be off. If the autopilot has an attitude hold mode, it should be engaged. The autopilot

attitude hold mode can usually maintain attitude more successfully than a pilot under stress. With the autopilot off, the yaw damper should be engaged. Controllability of the aircraft in turbulence becomes more difficult with the yaw damper off. Rudder controls should be centered before engaging the yaw damper.

(4) When flight through a thunderstorm cannot be avoided, turn up the intensity of panel and cabin lights so lightening does not cause temporary blindness. White lighting in the cockpit is better than red lighting during thunderstorms.

(5) Keep wings level and maintain the desired pitch attitude and approximate heading. Do not attempt to turn around and fly out of the storm because the speed associated with thunderstorms usually makes such attempts unsuccessful. Use smooth, moderate control movements to resist changes in attitude. If large attitude changes occur, avoid abrupt or large control inputs. Avoid, as much as possible, use of the stabilizer trim in controlling pitch attitudes. Do not chase altitude.

**12. FLIGHT TRAINING.** Flight training required to comply with FAR § 61.31(f) may be conducted in a high-altitude airplane or a simulator that meets the requirements of FAR § 121.407. The simulator should be representative of an airplane that has a service ceiling or maximum operating altitude, whichever is lower, above 25,000 feet MSL. The training should consist of as many flights as necessary to cover the following procedures and maneuvers. Each flight should consist of a preflight briefing, flight planning, a preflight inspection (if an airplane is being used), demonstrations by the instructor of certain maneuvers or procedures when necessary, and a postflight briefing and discussion.

***a. Preflight Briefing.*** The instructor should verbally cover the material that will be introduced during the flight. If more than one flight is required, previous flights should be reviewed at this time. The preflight briefing is a good time to go over any questions the trainee may have regarding operations at high altitudes or about the aircraft itself. Questions by the trainee should be encouraged during all portions of the flight training.

***b. Preflight Planning.*** A thorough flight plan should be completed for a predetermined route. The flight plan should include a complete weather briefing. If possible, a trip to a Flight Service Station (FSS) is encouraged rather than a telephone briefing so the trainee can use actual weather charts. Winds, pilot reports, the freezing level and other meteorological information obtained from the briefing should be used to determine the best altitude for the flight. The information should be retained for future calculations.

(1) The course should be plotted on a high-altitude navigation chart noting the appropriate jet routes and required reporting points on a navigation log. Low-altitude charts should be available for planning departures and arrivals to comply with airspace and airspeed requirements. Alternate airports should also be identified and noted.

(2) The Airplane Flight Manual should be reviewed with particular attention to weight and balance, performance charts, and emergency procedures. Oxygen requirements, airspeeds, groundspeeds, time en route, and fuel burn should be calculated using the Airplane Flight Manual and weather data, when applicable. Fuel management and descents should also be planned at this time. The Airplane Flight Manual should be readily

accessible in the cabin in the event of an emergency.

(3) A flight plan should be completed using appropriate jet routes from the enroute high-altitude chart. The flight plan should be filed with the local FSS.

*c. **Preflight Inspection.*** The aircraft checklist should be followed carefully. Particular attention should be given to the aircraft's fuselage, windshields, window panels, and canopies to identify any cracks or damage that could rupture under the stress of cabin pressurization. The inspection should include a thorough examination of the aircraft oxygen equipment, including available supply, an operational check of the system, and assurance that the supplemental oxygen is in a readily accessible location.

*d. **Runup, Takeoff and Initial Climb.*** Procedures in the Airplane Flight Manual should be followed, particularly the manufacturer's recommended power settings and airspeeds to avoid overboosting the engine. Standard call-out procedures are highly recommended and should be used for each phase of flight where the airplane crew consists of more than one crewmember.

*e. **Climb to high altitude and normal cruise operations while operating above 25,000 feet MSL.*** The transition from low to high altitude should be performed repeatedly to assure familiarity with appropriate procedures. Specific oxygen requirements should be met when climbing above 12,500 feet and pressurization should be adjusted with altitude. When passing through FL 180, the altimeter should be set to 29.92 and left untouched until descending below that altitude. Reporting points should be complied with, as should appropriate altitude selection for direction of flight. Throughout the entire climb and cruise above 25,000 feet, emphasis should be given to monitoring cabin pressurization.

*f. Simulated Emergencies.* Training should include at least one simulated rapid decompression and emergency descent. Do not actually depressurize the airplane for this or any other training. Actual decompression of an airplane can be extremely dangerous and should never be done intentionally for training purposes. The decompression should be simulated by donning the oxygen masks, turning on the supplemental oxygen controls, configuring the airplane for an emergency descent, and performing the emergency descent as soon as possible. This maneuver can be practiced at any altitude.

*g. Descents.* Gradual descents from altitude should be practiced to provide passenger comfort and compliance with procedures for transitioning out of the high-altitude realm of flight. The airplane manufacturer's recommendations should be followed with regard to descent power settings to avoid stress on the engine and excessive cooling. Particular emphasis should be given to cabin pressurization and procedures for equalizing cabin and ambient pressures before landing. Emphasis should also be given to changing to low-altitude charts when transitioning through FL 180, obtaining altimeter settings below FL 180, and complying with airspace and airspeed restrictions at appropriate altitudes.

***h. Engine Shutdown.*** Allow the turbocharged engine to cool for at least 1 minute and assure that all shutdown procedures in the Airplane Flight Manual are followed. Before exiting the airplane, always check that all oxygen equipment has been turned off and that the valves on that equipment are closed.

***i. Postflight Discussion.*** The instructor should review the flight and answer any questions the trainee may have. If additional flights are necessary to ensure thorough understanding of high-altitude operations, the material for the next flight should be previewed during the postflight discussion.